This print-out should have 42 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

001 10.0 points

High-speed stroboscopic photographs show that the head of a 216 g golf club is traveling at 49.5 m/s just before it strikes a 45.9 g golf ball at rest on a tee. After the collision, the club head travels (in the same direction) at 33.7 m/s.

Find the speed of the golf ball immediately after impact.

Correct answer: 74.3529 m/s.

Explanation:

$$\text{Let :}\quad m_1 = 216\text{ g}\,,\quad v_1 = 49.5\text{ m/s}\,,\quad m_2 = 45.9\text{ g}\,,\quad\text{and}\quad v_1' = 33.7\text{ m/s}\,.$$

By conservation of momentum

$$m_1\,v_1 + 0 = m_1\,v_1' + m_2\,v_2'$$

$$m_2\,v_2' = m_1\,v_1 - m_1\,v_1'$$

$$\begin{aligned} v_2' &= \frac{m_1}{m_2}\,(v_1 - v_1') \\ &= \frac{216\text{ g}}{45.9\text{ g}}\,(49.5\text{ m/s} - 33.7\text{ m/s}) \\ &= \boxed{74.3529\text{ m/s}}\,. \end{aligned}$$

002 10.0 points

A 14 g toy car moving to the right at 23 cm/s has a head-on nearly elastic collision with a 23 g toy car moving in the opposite direction at 34 cm/s. After colliding, the 14 g car moves with a velocity of 47 cm/s to the left.

Find the speed of the second car after the collision.

Correct answer: 8.6087 cm/s.

Explanation:

Basic Concept:

$$m_1\vec{v}_{1,i} + m_2\vec{v}_{2,i} = m_1\vec{v}_{1,f} + m_2\vec{v}_{2,f}$$

Given: Let to the right be positive:

$$\begin{aligned} m_1 &= 14\text{ g}\,, \\ v_{1,i} &= +23\text{ cm/s}\,, \\ m_2 &= 23\text{ g}\,, \\ v_{2,i} &= -34\text{ cm/s}\,, \\ v_{1,f} &= 47\text{ cm/s}\,, \end{aligned}$$

Solution:

$$\begin{aligned} v_{2,f} &= \frac{m_1\,v_{1,i} + m_2\,v_{2,i} - m_1\,v_{1,f}}{m_2} \\ &= \frac{m_1\,v_{1,i}}{m_2} + v_{2,i} - \frac{m_1\,v_{1,f}}{m_2} \\ &= \frac{(14\text{ g})\,(23\text{ cm/s})}{23\text{ g}} + (-34\text{ cm/s}) \\ &\quad - \frac{(14\text{ g})\,(-47\text{ cm/s})}{23\text{ g}} \\ &= 8.6087\text{ cm/s} \end{aligned}$$

to the right.

003 (part 1 of 2) 10.0 points

A 0.17 kg baseball moving at +30 m/s is slowed to a stop by a catcher who exerts a constant force of −370 N.

a) How long does it take this force to stop the ball?

Correct answer: 0.0137838 s.

Explanation:

$$\text{Let :}\quad m = 0.17\text{ kg}\,,\quad v_f = 30\text{ m/s}\,,\quad\text{and}\quad F = -370\text{ N}\,.$$

Since $v_f = 0$ m/s,

$$\begin{aligned} \vec{F}\,\Delta t &= m\,\vec{v}_f - m\,\vec{v}_i = -m\,\vec{v}_i \\ \Delta t &= \frac{-m\,v_i}{F} \\ &= \frac{-(0.17\text{ kg})\,(30\text{ m/s})}{-370\text{ N}} \\ &= \boxed{0.0137838\text{ s}}\,. \end{aligned}$$

004 (part 2 of 2) 10.0 points

b) How far does the ball travel before stopping?

Correct answer: 0.206757 m.

Explanation:

Since $v_f = 0$ m/s,

$$\begin{aligned}\Delta x &= \frac{v_i + v_f}{2}\,\Delta t = \frac{v_i}{2}\,\Delta t\\ &= \frac{30\text{ m/s}}{2}\,(0.0137838\text{ s})\\ &= \boxed{0.206757\text{ m}}.\end{aligned}$$

005 (part 1 of 2) 10.0 points

A railroad car with a mass of 2.02×10^4 kg moving at 3.22 m/s collides and joins with two railroad cars already joined together, each with the same mass as the single car and initially moving in the same direction at 1.37 m/s.

a) What is the final speed of the three joined cars after the collision?

Correct answer: 1.98667 m/s.

Explanation:

Let:

$$\begin{aligned}m_1 &= 2.02 \times 10^4\text{ kg}\\ v_{i,1} &= 3.22\text{ m/s}\\ m_2 &= 2m_1\\ v_{i,2} &= 1.37\text{ m/s} \quad\text{and}\\ m_3 &= m_1 + m_2 = 3m_1\,.\end{aligned}$$

$$\begin{aligned}m_1\,\vec{v}_{i,1} + m_2\,\vec{v}_{i,2} &= (m_1 + m_2)\,\vec{v}_f\\ v_f &= \frac{m_1\,v_{i,1} + (2\,m_1)\;v_{i,2}}{3\,m_1}\\ &= \frac{v_{i,1} + 2\,v_{i,2}}{3}\\ &= \frac{3.22\text{ m/s} + 2\,(1.37\text{ m/s})}{3}\\ &= \boxed{1.98667\text{ m/s}}.\end{aligned}$$

006 (part 2 of 2) 10.0 points

b) What is the decrease in kinetic energy during the collision?

Correct answer: 23044.8 J.

Explanation:

Basic Concepts:

$$KE = \frac{1}{2}\,m\,v^2$$

$$\Delta KE = KE_f - KE_i$$

Solution:

$$KE_f = \frac{1}{2}\,(3\,m_1)\;v_f^2$$

and

$$KE_i = \frac{1}{2}\,m_1\,v_{i,1}^2 + \frac{1}{2}\,(2\,m_1)\;v_{i,2}^2$$

so

$$\begin{aligned}\Delta KE &= \frac{3}{2}\,m_1\,v_f^2 - \frac{1}{2}\,m_1\,v_{i,1}^2 - m_1\,v_{i,2}^2\\ &= m_1\left[\frac{3}{2}\,v_f^2 - \frac{1}{2}\,v_{i,1}^2 - v_{i,2}^2\right]\\ &= (20200\text{ kg})\bigg(\frac{3}{2}[1.98667\text{ m/s}]^2\\ &\qquad - \frac{1}{2}[3.22\text{ m/s}]^2 - [1.37\text{ m/s}]^2\bigg)\\ &= \boxed{-23044.8\text{ m/s}},\end{aligned}$$

which is a decrease of 23044.8 J.

007 (part 1 of 3) 10.0 points

A 5.9 kg bowling ball sliding to the right at 6.69 m/s has an elastic head-on collision with another 5.9 kg bowling ball initially at rest. The first ball stops after the collision.

Find the velocity of the second ball after the collision.

Correct answer: 6.69 m/s.

Explanation:

$$\text{Let}: \quad m_1 = m_2 = m = 5.9\text{ kg} \quad\text{and}\quad v_{1,i} = +6.69\text{ m/s}\,.$$

where positive is to the right.

Since $v_{2,i} = 0$ m/s and $v_{1,f} = 0$ m/s,

$$\begin{aligned} m_1\,\vec{v}_{1,i} + m_2\,\vec{v}_{2,i} &= m_1\,\vec{v}_{1,f} + m_2\,\vec{v}_{2,f} \\ m\,\vec{v}_{1,i} &= m\,\vec{v}_{2,f} \\ v_{2,f} = v_{1,i} &= \boxed{6.69 \text{ m/s}}\,, \end{aligned}$$

which is 6.69 m/s to the right.

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008 (part 2 of 3) 10.0 points

What is the total kinetic energy before the collision?

Correct answer: 132.03 J.

Explanation:

$v_{2,i} = 0$ m/s, so

$$\begin{aligned} KE_i &= \frac{1}{2}\,m_1\,v_{1,i}^2 = \frac{1}{2}\,(5.9 \text{ kg})(6.69 \text{ m/s})^2 \\ &= \boxed{132.03 \text{ J}}\,. \end{aligned}$$

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009 (part 3 of 3) 10.0 points

What is the total kinetic energy after the collision?

Correct answer: 132.03 J.

Explanation:

$v_{1,f} = 0$ m/s, so

$$\begin{aligned} KE_f &= \frac{1}{2}\,m_2\,v_{2,f}^2 = \frac{1}{2}\,(5.9 \text{ kg})(6.69 \text{ m/s})^2 \\ &= \boxed{132.03 \text{ J}}\,. \end{aligned}$$

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010 (part 1 of 3) 10.0 points

Each croquet ball in a set has a mass of 0.47 kg. The green ball, traveling at 13.7 m/s, strikes the blue ball, which is at rest.

Assuming that the balls slide on a frictionless surface and all collisions are head-on, find the final speed of the blue ball in each of the following situations:

a) The green ball stops moving after it strikes the blue ball.

Correct answer: 13.7 m/s.

Explanation:

$$\text{Let}: \quad \begin{aligned} m_g &= 0.47 \text{ kg}\,, \\ m_b &= 0.47 \text{ kg}\,, \\ v_{i,g} &= 13.7 \text{ m/s}\,, \quad \text{and} \\ v_{f,g} &= 0 \text{ m/s}\,. \end{aligned}$$

Since $v_{i,b} = 0$ m/s and $m_g = m_b$,

$$\begin{aligned} m_g \vec{v}_{i,g} &= m_g \vec{v}_{f,g} + m_b \vec{v}_{f,b} \\ \vec{v}_{i,g} &= \vec{v}_{f,g} + \vec{v}_{f,b} \end{aligned}$$

$$v_{f,b} = v_{i,g} = \boxed{13.7 \text{ m/s}}\,.$$

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011 (part 2 of 3) 10.0 points

b) The green ball continues moving after the collision at 2.8 m/s in the same direction.

Correct answer: 10.9 m/s.

Explanation:

$$\text{Let}: \quad v_{f,g} = 2.8 \text{ m/s}\,.$$

$$\begin{aligned} v_{f,b} = v_{i,g} - v_{f,g} &= 13.7 \text{ m/s} - 2.8 \text{ m/s} \\ &= \boxed{10.9 \text{ m/s}}\,. \end{aligned}$$

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012 (part 3 of 3) 10.0 points

c) The green ball continues moving after the collision at 0.5 m/s in the same direction.

Correct answer: 13.2 m/s.

Explanation:

$$\text{Let}: \quad v_{f,g} = 0.5 \text{ m/s}\,.$$

$$\begin{aligned} v_{f,b} = v_{i,g} - v_{f,g} &= 13.7 \text{ m/s} - 0.5 \text{ m/s} \\ &= \boxed{13.2 \text{ m/s}}\,. \end{aligned}$$

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013 (part 1 of 2) 10.0 points

An 82 kg fullback moving east with a speed of 5.6 m/s is tackled by a 91 kg opponent running west at 3.7 m/s, and the collision is perfectly inelastic.

a) What is the velocity of the players immediately after the tackle?

Correct answer: 0.708092 m/s.

Explanation:
Basic Concept: The two players have the same final speed, so

$$m_1\vec{v}_{i,1} + m_2\vec{v}_{i,2} = (m_1 + m_2)\vec{v}_f$$

Given: Let east be positive:

$$\begin{aligned} m_1 &= 82 \text{ kg} \\ v_{i,1} &= 5.6 \text{ m/s} \\ m_2 &= 91 \text{ kg} \\ v_{i,2} &= -3.7 \text{ m/s} \end{aligned}$$

Solution:

$$\begin{aligned} v_f &= \frac{m_1 v_{i,1} + m_2 v_{i,2}}{(m_1 + m_2)} \\ &= \frac{(82 \text{ kg})(5.6 \text{ m/s}) + (91 \text{ kg})(-3.7 \text{ m/s})}{82 \text{ kg} + 91 \text{ kg}} \\ &= 0.708092 \text{ m/s} \end{aligned}$$

to the east.

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014 (part 2 of 2) 10.0 points

b) What is the decrease in kinetic energy during the collision?

Correct answer: 1865.28 J.

Explanation:
Basic Concepts:

$$KE = \frac{1}{2}mv^2$$

$$\Delta KE = KE_f - KE_i$$

Solution:

$$KE_f = \frac{1}{2}(m_1 + m_2)v_f^2$$

and

$$KE_i = \frac{1}{2}m_1 v_{i,1}^2 + \frac{1}{2}m_2 v_{i,2}^2$$

so

$$\begin{aligned} \Delta KE &= \frac{1}{2}(m_1 + m_2)v_f^2 - \frac{1}{2}m_1 v_{i,1}^2 \\ &\quad - \frac{1}{2}m_2 v_{i,2}^2 \\ &= \frac{1}{2}(82 \text{ kg} + 91 \text{ kg}) \\ &\quad \cdot (-0.708092 \text{ m/s})^2 \\ &\quad - \frac{1}{2}(82 \text{ kg})(5.6 \text{ m/s})^2 \\ &\quad - \frac{1}{2}(91 \text{ kg})(-3.7 \text{ m/s})^2 \\ &= -1865.28 \text{ m/s} \end{aligned}$$

which is a decrease of 1865.28 J.

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015 (part 1 of 2) 10.0 points

A 47.7 kg student runs down the sidewalk and jumps with a horizontal speed of 4.21 m/s onto a stationary skateboard. The student and skateboard move down the sidewalk with a speed of 3.93 m/s.

a) Find the mass of the skateboard.

Correct answer: 3.39847 kg.

Explanation:
Basic Concept:

$$\begin{aligned} m_b\vec{v}_{i,b} + m_s\vec{v}_{i,s} &= (m_b + m_s)\vec{v}_f \\ m_b\vec{v}_{i,b} &= (m_b + m_s)\vec{v}_f \end{aligned}$$

since $v_{i,s} = 0$ m/s.
Given: Let to the right be positive:

$$\begin{aligned} m_b &= 47.7 \text{ kg} \\ v_{i,b} &= 4.21 \text{ m/s} \\ v_f &= 3.93 \text{ m/s} \end{aligned}$$

Solution:

$$\begin{aligned} m_b v_{i,b} &= m_b v_f + m_s v_f \\ m_s &= \frac{m_b(v_{i,b} - v_f)}{v_f} \\ &= \frac{(47.7 \text{ kg})(4.21 \text{ m/s} - 3.93 \text{ m/s})}{3.93 \text{ m/s}} \\ &= 3.39847 \text{ kg} \end{aligned}$$

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016 (part 2 of 2) 10.0 points

b) How fast would the student have to jump to have a final speed of 6.85 m/s?

Correct answer: 7.33804 m/s.

Explanation:
Given:

$$v_f = 6.85 \text{ m/s}$$

Solution:

$$\begin{aligned} v_{i,b} &= \frac{(m_b + m_s)v_f}{m_b} \\ &= \frac{(47.7 \text{ kg} + 3.39847 \text{ kg})(6.85 \text{ m/s})}{47.7 \text{ kg}} \\ &= 7.33804 \text{ m/s} \end{aligned}$$

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017 10.0 points

A 2071 kg car moving east at 13.26 m/s collides with a 3234 kg car moving north. The cars stick together and move as a unit after the collision, at an angle of 30.7° north of east and at a speed of 6.02 m/s.

What was the speed of the 3234 kg car before the collision?

Correct answer: 5.04167 m/s.

Explanation:

Let east and north be positive:

$$\begin{aligned} \text{Given}: \quad m_1 &= 2071 \text{ kg}\,, \\ v_{1i} &= +13.26 \text{ m/s}\,, \\ m_2 &= 3234 \text{ kg}\,, \quad \text{and} \\ v_f &= +6.02 \text{ m/s}\,. \end{aligned}$$

Vertically,

$$\begin{aligned} m_2\, v_{2i} &= (m_1 + m_2)\, v_f \, \sin\theta \\ v_{2i} &= \frac{(m_1 + m_2)\, v_f \, \sin\theta}{m_2} \\ &= \frac{2071 \text{ kg} + 3234 \text{ kg}}{3234 \text{ kg}} \\ &\quad \cdot (6.02 \text{ m/s}) \, \sin 30.7^\circ \\ &= \boxed{5.04167 \text{ m/s}}\,. \end{aligned}$$

Notice that the initial velocity of the 2071 kg car was unnecessary for this solution.

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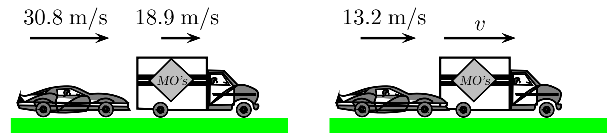
018 (part 1 of 2) 10.0 points

A 956 kg car traveling initially with a speed of 30.8 m/s in an easterly direction crashes into the rear end of a 9830 kg truck moving in the same direction at 18.9 m/s. The velocity of the car right after the collision is 13.2 m/s to the east.



What is the velocity of the truck immediately after the collision?

Correct answer: 20.6117 m/s.

Explanation:

$$\begin{aligned} \text{Let}: \quad m_1 &= 956 \text{ kg}\,, \\ v_1 &= 30.8 \text{ m/s}\,, \\ m_2 &= 9830 \text{ kg}\,, \\ v_2 &= 18.9 \text{ m/s}\,, \quad \text{and} \\ v_1' &= 13.2 \text{ m/s}\,. \end{aligned}$$

From conservation of momentum

$$m_1\, v_1 + m_2\, v_2 = m_1\, v_1' + m_2\, v_2'$$

$$\begin{aligned} v_2' &= \frac{m_1\, v_1 + m_2\, v_2 - m_1\, v_1'}{m_2} \\ &= \frac{(956 \text{ kg})\,(30.8 \text{ m/s})}{9830 \text{ kg}} \\ &\quad + \frac{(9830 \text{ kg})\,(18.9 \text{ m/s})}{9830 \text{ kg}} \\ &\quad - \frac{(956 \text{ kg})\,(13.2 \text{ m/s})}{9830 \text{ kg}} \\ &= \boxed{20.6117 \text{ m/s}} \end{aligned}$$

directed to the east.

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019 (part 2 of 2) 10.0 points

How much mechanical energy is lost in the collision?

Correct answer: 37759.5 J.

Explanation:

The initial kinetic energy is

$$K_i = \frac{1}{2}\, m_1\, v_1^2 + \frac{1}{2}\, m_2\, v_2^2\,,$$

and the final kinetic energy

$$K_f = m_1 (v_1')^2 + m_2 (v_2')^2$$

The change in kinetic energy is

$$\begin{aligned} \Delta K &= K_f - K_i \\ &= \frac{1}{2}\, m_1 \left(v'^2_1 - v_1^2 \right) \\ &\quad + \frac{1}{2}\, m_2 \left(v'^2_2 - v_2^2 \right) \\ &= \frac{1}{2}\,(956\text{ kg})\left[(13.2\text{ m/s})^2 - (30.8\text{ m/s})^2\right] \\ &\quad + \frac{1}{2}\,(9830\text{ kg}) \\ &\qquad \times \left[(20.6117\text{ m/s})^2 - (18.9\text{ m/s})^2\right] \\ &= -37759.5\text{ J}\,, \end{aligned}$$

a loss of $\boxed{37759.5\text{ J}}$, which is converted into internal energy.

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020 (part 1 of 2) 10.0 points

A 0.23 kg arrow with a velocity of 11 m/s to the west strikes and pierces the center of a 3.0 kg target.

What is the final velocity of the combined mass?

Correct answer: −0.783282 m/s.

Explanation:

$$\text{Let}: \quad \begin{aligned} m_a &= 0.23\text{ kg}\,, \\ v_{i,a} &= -11\text{ m/s}\,, \quad \text{and} \\ m_t &= 3.0\text{ kg}\,, \end{aligned}$$

where east is positive.

The arrow and target have the same final speed, so from conservation of momentum,

$$\begin{aligned} m_a\, v_{i,a} + m_t\, v_{i,t} &= (m_a + m_t)\, v_f \\ m_a\, v_{i,a} &= (m_a + m_t\, v_f \\ v_f &= \frac{m_a v_{i,a}}{m_a + m_t} \\ &= \frac{(0.23\text{ kg})(-11\text{ m/s})}{0.23\text{ kg} + 3\text{ kg}} \\ &= \boxed{-0.783282\text{ m/s}}\,, \end{aligned}$$

which is 0.783282 m/s to the west.

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021 (part 2 of 2) 10.0 points

What is the decrease in kinetic energy during the collision?

Correct answer: 12.9241 J.

Explanation:

The kinetic energies are

$$K_f = \frac{1}{2}\,(m_a + m_t)\, v_f^2 \quad \text{and}$$

$$K_i = \frac{1}{2}\, m_a\, v_{i,a}^2 + \frac{1}{2}\, m_t\, v_{i,t}^2 = \frac{1}{2}\, m_a\, v_{i,a}^2\,.$$

$$\begin{aligned} \Delta KE = K_f - K_i &= \frac{1}{2}(m_a + m_t) v_f^2 - \frac{1}{2} m_a v_{i,a}^2 \\ &= \frac{1}{2}\,(0.23\text{ kg} + 3\text{ kg}) \\ &\quad \times (-0.783282\text{ m/s})^2 \\ &\quad - \frac{1}{2}\,(0.23\text{ kg})(-11\text{ m/s})^2 \\ &= -12.9241\text{ J}\,, \end{aligned}$$

which is a decrease of $\boxed{12.9241\text{ J}}$.

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022 10.0 points

What is the momentum of a 0.141 kg baseball thrown with a velocity of 35 m/s toward home plate?

Correct answer: 4.935 kg · m/s.

Explanation:

$$\text{Let}: \quad \begin{aligned} m &= 0.141\text{ kg} \quad \text{and} \\ v &= 35\text{ m/s}\,. \end{aligned}$$

$$\begin{aligned} \vec{p} &= m\, \vec{v} \\ p &= m\, v \\ &= (0.141\text{ kg})\,(35\text{ m/s}) \\ &= \boxed{4.935\text{ kg} \cdot \text{m/s}} \end{aligned}$$

toward home plate.

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023 10.0 points

Two carts with masses of 4.9 kg and 3.7 kg move toward each other on a frictionless track with speeds of 5.9 m/s and 4.7 m/s, respectively. The carts stick together after colliding head-on.

Find their final speed.

Correct answer: 1.33953 m/s.

Explanation:

Basic Concept:

$$m_1\vec{v}_{i,1} + m_2\vec{v}_{i,2} = (m_1 + m_2)\vec{v}_f$$

Given:

Let the first velocity be positive:

$$\begin{aligned} m_1 &= 4.9 \text{ kg} \\ m_2 &= 3.7 \text{ kg} \\ v_{i,1} &= 5.9 \text{ m/s} \\ v_{i,2} &= -4.7 \text{ m/s} \end{aligned}$$

Solution:

$$\begin{aligned} v_f &= \frac{m_1 v_{i,1} + m_2 v_{i,2}}{m_1 + m_2} \\ &= \frac{(4.9 \text{ kg})(5.9 \text{ m/s}) + (3.7 \text{ kg})(-4.7 \text{ m/s})}{4.9 \text{ kg} + 3.7 \text{ kg}} \\ &= 1.33953 \text{ m/s} \end{aligned}$$

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024 (part 1 of 3) 10.0 points

A 24 kg child is riding a 6.0 kg bike with a velocity of 5.2 m/s to the northwest.

a) What is the total momentum of the child and the bike together?

Correct answer: 156 kg · m/s.

Explanation:

$$\begin{aligned} \text{Let}: \quad m_1 &= 24 \text{ kg}, \\ m_2 &= 6.0 \text{ kg}, \quad \text{and} \\ v &= 5.2 \text{ m/s to the northwest.} \end{aligned}$$

$$\begin{aligned} \vec{p} &= m\vec{v} \\ p_{tot} &= (m_1 + m_2)\, v \\ &= (24 \text{ kg} + 6 \text{ kg})\,(5.2 \text{ m/s}) \\ &= (30 \text{ kg})\,(5.2 \text{ m/s}) \\ &= \boxed{156 \text{ kg} \cdot \text{m/s}} \end{aligned}$$

to the northwest.

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025 (part 2 of 3) 10.0 points

b) What is the momentum of the child?

Correct answer: 124.8 kg · m/s.

Explanation:

$$\begin{aligned} p_1 &= m_1\, v \\ &= (24 \text{ kg})\,(5.2 \text{ m/s}) \\ &= \boxed{124.8 \text{ kg} \cdot \text{m/s}} \end{aligned}$$

to the northwest.

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026 (part 3 of 3) 10.0 points

c) What is the momentum of the bike?

Correct answer: 31.2 kg · m/s.

Explanation:

$$\begin{aligned} p_2 &= m_2\, v \\ &= (6 \text{ kg})\,(5.2 \text{ m/s}) \\ &= \boxed{31.2 \text{ kg} \cdot \text{m/s}} \end{aligned}$$

to the northwest

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027 10.0 points

An ostrich with a mass of 145 kg is running to the right with a velocity of 18 m/s.

Find the momentum of the ostrich.

Correct answer: 2610 kg · m/s.

Explanation:

$$\begin{aligned} \text{Let}: \quad m &= 145 \text{ kg} \quad \text{and} \\ v &= 18 \text{ m/s} \quad \text{to the right}. \end{aligned}$$

$$\begin{aligned} p &= m\,v \\ &= (145 \text{ kg})\,(18 \text{ m/s}) \\ &= \boxed{2610 \text{ kg}\cdot\text{m/s}} \end{aligned}$$

to the right.

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028 (part 1 of 2) 10.0 points

During practice, a student kicks a 0.47 kg soccer ball with a velocity of 8.4 m/s to the south into a 0.20 kg bucket lying on its side. The bucket travels with the ball after the collision.

a) What is the final velocity of the combined mass?

Correct answer: -5.89254 m/s.

Explanation:

Basic Concept: The ball and bucket have the same final speed, so

$$\begin{aligned} m_1\vec{v}_{i,1} + ms_2\vec{v}_{i,2} &= (m_1+m_2)\vec{v}_f \\ m_1\vec{v}_{i,1} &= (m_1+m_2)\vec{v}_f \end{aligned}$$

since $v_{i,2} = 0$ m/s.

Given: Let south be negative:

$$\begin{aligned} m_1 &= 0.47 \text{ kg} \\ v_{i,1} &= -8.4 \text{ m/s} \\ m_2 &= 0.20 \text{ kg} \end{aligned}$$

Solution:

$$\begin{aligned} v_f &= \frac{m_1 v_{i,1}}{(m_1+m_2)} \\ &= \frac{(0.47 \text{ kg})(-8.4 \text{ m/s})}{0.47 \text{ kg} + 0.2 \text{ kg}} \\ &= -5.89254 \text{ m/s} \end{aligned}$$

which is 5.89254 m/s to the south.

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029 (part 2 of 2) 10.0 points

b) What is the decrease in kinetic energy during the collision?

Correct answer: 4.94973 J.

Explanation:

Basic Concepts:

$$KE = \frac{1}{2}mv^2$$

$$\Delta KE = KE_f - KE_i$$

Solution:

$$KE_f = \frac{1}{2}\,(m_1+m_2)\,v_f^2$$

and

$$\begin{aligned} KE_i &= \frac{1}{2}m_1 v_{i,1}^2 + \frac{1}{2}m_2 v_{i,2}^2 \\ &= \frac{1}{2}m_1 v_{i,1}^2 \end{aligned}$$

since $v_{i,2} = 0$ m/s.

$$\begin{aligned} \Delta KE &= \frac{1}{2}(m_1+m_2)v_f^2 - \frac{1}{2}m_1 v_{i,1}^2 \\ &= \frac{1}{2}(0.47 \text{ kg} + 0.2 \text{ kg}) \\ &\qquad \cdot (-5.89254 \text{ m/s})^2 \\ &\qquad\qquad - \frac{1}{2}(0.47 \text{ kg})(-8.4 \text{ m/s})^2 \\ &= -4.94973 \text{ m/s} \end{aligned}$$

which is a decrease of 4.94973 J.

---

030 10.0 points

Note: Take East as the positive direction.

A(n) 86 kg fisherman jumps from a dock into a 134 kg rowboat at rest on the West side of the dock.

If the velocity of the fisherman is 3.5 m/s to the West as he leaves the dock, what is the final velocity of the fisherman and the boat?

Correct answer: -1.36818 m/s.

Explanation:

Let West be negative:

$$\begin{aligned} \text{Let}: \quad m_1 &= 86 \text{ kg kg}\,, \\ m_2 &= 134 \text{ kg kg}\,, \quad \text{and} \\ v_{i,1} &= -3.5 \text{ m/s m/s}\,. \end{aligned}$$

The boat and fisherman have the same final speed, and $v_{i,2} = 0$ m/s, so

$$\begin{aligned} m_1\,\vec{v}_{i,1} + m_2\,\vec{v}_{i,2} &= (m_1+m_2)\,\vec{v}_f \\ m_1\,\vec{v}_{i,1} &= (m_1+m_2)\,\vec{v}_f \end{aligned}$$

$$\begin{aligned} v_f &= \frac{m_1\, v_i}{m_1 + m_2} \\ &= \frac{(86 \text{ kg})\,(-3.5 \text{ m/s})}{86 \text{ kg} + 134 \text{ kg}} \\ &= \boxed{-1.36818 \text{ m/s}}, \end{aligned}$$

which is 1.36818 m/s to the West.

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031 (part 1 of 2) 10.0 points

A 0.13 kg ball of dough is thrown straight up into the air with an initial speed of 14 m/s.

The acceleration of gravity is 9.8 m/s^2.

What is its momentum at its maximum height?

Correct answer: 0 kg m/s.

Explanation:

$$\begin{aligned} \text{Let :} \quad v_i &= 14 \text{ m/s}, \\ m &= 0.13 \text{ kg}, \quad \text{and} \\ v_f &= 0 \text{ m/s}, \end{aligned}$$

at the dough's maximum height.

$$\vec{p} = m\,\vec{v}$$

$$p = (0.13 \text{ kg})\,(0 \text{ m/s}) = \boxed{0 \text{ kg m/s}}.$$

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032 (part 2 of 2) 10.0 points

What is its momentum halfway to its maximum height?

Correct answer: 1.28693 kg m/s.

Explanation:

At the maximum height $v = 0$, so

$$v_f^2 = v_i^2 + 2\,g\,\Delta y = 0\,,$$

so half of that height is

$$\begin{aligned} \Delta y &= \frac{1}{2}\,\frac{-v_i^2}{2\,g} \\ &= \frac{-(14 \text{ m/s})^2}{4\,(9.8 \text{ m/s}^2)} \\ &= 5 \text{ m} \end{aligned}$$

For the velocity at half of the maximum height, we have

$$\begin{aligned} v_f^2 &= v_i^2 + 2\,g\,\Delta y \\ &= (14 \text{ m/s})^2 - 2\,\left(9.8 \text{ m/s}^2\right)\,(5 \text{ m}) \\ &= 98 \text{ m}^2/\text{s}^2 \\ \|\vec{v}\| &= \sqrt{98 \text{ m}^2/\text{s}^2} \\ &= 9.89949 \text{ m/s}\,. \end{aligned}$$

It is directed upward, and the magnitude of its momentum is

$$\begin{aligned} \|\vec{p}\| &= m\,\|\vec{v}\| \\ &= (0.13 \text{ kg})\,(9.89949 \text{ m/s}) \\ &= \boxed{1.28693 \text{ kg m/s}}. \end{aligned}$$

---

033 10.0 points

A 1400 kg car traveling at 17.9 m/s to the south collides with a 3800 kg truck that is initially at rest at a stoplight. The car and truck stick together and move together after the collision.

What is the final velocity of the two-vehicle mass?

Correct answer: -4.81923 m/s.

Explanation:

Basic Concept:

$$\begin{aligned} m_c\vec{v}_{i,c} + m_t\vec{v}_{i,t} &= (m_c + m_t)\vec{v}_f \\ m_c\vec{v}_{i,c} &= (m_c + m_t)\vec{v}_f \end{aligned}$$

since $v_{i,t} = 0$ m/s.

Given: Let north be positive:

$$\begin{aligned} m_c &= 1400 \text{ kg} \\ m_t &= 3800 \text{ kg} \\ v_{i,c} &= -17.9 \text{ m/s} \end{aligned}$$

Solution:

$$\begin{aligned} v_f &= \frac{m_c v_{i,c}}{m_c + m_t} \\ &= \frac{(1400 \text{ kg})(-17.9 \text{ m/s})}{1400 \text{ kg} + 3800 \text{ kg}} \\ &= -4.81923 \text{ m/s} \end{aligned}$$

which is 4.81923 m/s to the south.

---

034 10.0 points

A dry cleaner throws a 21 kg bag of laundry onto a stationary 8.5 kg cart. The cart and laundry bag begin moving at 2.6 m/s to the right.

Find the velocity of the laundry bag before the collision.

Correct answer: 3.65238 m/s.

Explanation:

Basic Concept:

$$m_b \vec{v}_{i,b} + m_c \vec{v}_{i,c} = (m_b + m_c)\vec{v}_f$$
$$m_b \vec{v}_{i,b} = (m_b + m_c)\vec{v}_f$$

since $v_{i,c} = 0$ m/s.

Given: Let to the right be positive:

$$m_b = 21 \text{ kg}$$
$$m_c = 8.5 \text{ kg}$$
$$v_f = 2.6 \text{ m/s}$$

Solution:

$$\begin{aligned} v_i &= \frac{(m_b + m_c)v_f}{m_b} \\ &= \frac{(21 \text{ kg} + 8.5 \text{ kg})(2.6 \text{ m/s})}{21 \text{ kg}} \\ &= 3.65238 \text{ m/s} \end{aligned}$$

to the right.

---

035 10.0 points

A football punter accelerates a 0.57 kg football from rest to a speed of 12 m/s in 0.17 s.

What constant force does the punter exert on the ball?

Correct answer: 40.2353 N.

Explanation:

$$\begin{aligned} \text{Given :} \quad m &= 0.57 \text{ kg}\,, \\ v_f &= 12 \text{ m/s}, \quad \text{and} \\ \Delta t &= 0.17 \text{ s}\,. \end{aligned}$$

Applying impulse,

$$\vec{F}\Delta t = m\vec{v}_f - m\vec{v}_i = m\vec{v}_f$$

since $v_i = 0$ m/s.

$$\begin{aligned} F &= \frac{m\, v_f}{\Delta t} \\ &= \frac{(0.57 \text{ kg})\,(12 \text{ m/s})}{0.17 \text{ s}} \\ &= \boxed{40.2353 \text{ N}}\,. \end{aligned}$$

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036 (part 1 of 2) 10.0 points

A 65.7 kg ice skater moving to the right with a velocity of 2.54 m/s throws a 0.174 kg snowball to the right with a velocity of 40.1 m/s relative to the ground.

What is the velocity of the ice skater after throwing the snowball? Disregard the friction between the skates and the ice.

Correct answer: 2.44053 m/s.

Explanation:

Let forward be positive:

$$\begin{aligned} \text{Let :} \quad m_1 &= 65.7 \text{ kg}\,, \\ v_i &= 2.54 \text{ m/s}\,, \\ m_2 &= 0.174 \text{ kg}\,, \quad \text{and} \\ v_{2,f} &= 40.1 \text{ m/s}\,. \end{aligned}$$

The snowball has the same initial velocity as the skater, so

$$(m_1 + m_2)\,\vec{v}_i = m_1\,\vec{v}_{f,1} + m_2\,\vec{v}_{f,2}$$

$$\begin{aligned} m_1\,v_{f,1} &= (m_1 + m_2)\,v_i - m_2\,v_{f,2} \\ v_{f,1} &= \frac{(m_1 + m_2)\,v_i - m_2\,v_{f,2}}{m_1} \\ &= \frac{(65.7 \text{ kg} + 0.174 \text{ kg})\,(2.54 \text{ m/s})}{65.7 \text{ kg}} \\ &\quad - \frac{(0.174 \text{ kg})\,(40.1 \text{ m/s})}{65.7 \text{ kg}} \\ &= \boxed{2.44053 \text{ m/s}} \end{aligned}$$

forward.

---

037 (part 2 of 2) 10.0 points

A second skater initially at rest with a mass of 61.6 kg catches the snowball.

What is the velocity of the second skater after catching the snowball in a perfectly inelastic collision?

Correct answer: 0.11295 m/s.

Explanation:

$$\begin{aligned}\text{Let :}\quad m_1 &= 0.174\ \text{kg}\,,\\ v_{i,1} &= 40.1\ \text{m/s}\,,\quad \text{and}\\ m_2 &= 61.6\ \text{kg}\,.\end{aligned}$$

The snowball has the same final velocity as that of the skater, and $v_{i,2} = 0$ m/s, so

$$m_1\,\vec{v}_{i,1} = (m_1 + m_2)\,\vec{v}_f$$

$$\begin{aligned}(m_1 + m_2)\,v_f &= m_1\,v_{i,1}\\ v_f &= \frac{m_1\,v_{i,1}}{m_1 + m_2}\\ &= \frac{(0.174\ \text{kg})\,(40.1\ \text{m/s})}{0.174\ \text{kg} + 61.6\ \text{kg}}\\ &= \boxed{0.11295\ \text{m/s}}\,.\end{aligned}$$

---

038 10.0 points

What is the momentum of a two-particle system composed of a 1200 kg car moving east at 80 m/s and a second 1200 kg car moving west at 55 m/s? Let east be the positive direction.

Correct answer: 30000 kg · m/s.

Explanation:

$$\begin{aligned}\text{Let :}\quad m_1 &= 1200\ \text{kg}\,,\\ v_1 &= 80\ \text{m/s}\,,\\ m_2 &= 1200\ \text{kg}\,,\quad \text{and}\\ v_2 &= 55\ \text{m/s}\,.\end{aligned}$$

Thus

$$\begin{aligned}p &= m_1\,v_1 + m_2\,v_2\\ &= (1200\ \text{kg})(80\ \text{m/s})\\ &\quad + (1200\ \text{kg})(-55\ \text{m/s})\\ &= \boxed{30000\ \text{kg}\cdot\text{m/s}}\,.\end{aligned}$$

---

039 10.0 points

A 26.0 g marble sliding to the right at 23.0 cm/s overtakes and collides elastically with a 13.4 g marble moving in the same direction at 12.4 cm/s. After the collision, the 13.4 g marble moves to the right at 25.4 cm/s.

Find the velocity of the 26.0 g marble after the collision.

Correct answer: 16.3 cm/s.

Explanation:

Basic Concept:

$$m_1\vec{v}_{1,i} + m_2\vec{v}_{2,i} = m_1\vec{v}_{1,f} + m_2\vec{v}_{2,f}$$

Given: Let to the right be positive:

$$\begin{aligned}m_1 &= 26.0\ \text{g}\\ v_{1,i} &= +23.0\ \text{cm/s}\\ m_2 &= 13.4\ \text{g}\\ v_{2,i} &= +12.4\ \text{cm/s}\\ v_{2,f} &= +25.4\ \text{cm/s}\end{aligned}$$

Solution:

$$\begin{aligned}v_{1,f} &= \frac{m_1 v_{1,i} + m_2 v_{2,i} - m_2 v_{2,f}}{m_1}\\ &= v_{1,i} + \frac{m_2 v_{2,i} - m_2 v_{2,f}}{m_1}\\ &= 23\ \text{cm/s} + \frac{(13.4\ \text{g})(12.4\ \text{cm/s})}{26\ \text{g}}\\ &\qquad - \frac{(13.4\ \text{g})(25.4\ \text{cm/s})}{26\ \text{g}}\\ &= 16.3\ \text{cm/s}\end{aligned}$$

to the right.

---

040 (part 1 of 2) 10.0 points

A 2130 kg car traveling to the west at 18.1 m/s slows down uniformly under a force of 8880 N to the east.

a) How much force would be required to cause the same acceleration on a car of mass 3260 kg?

Correct answer: 13591 N.

Explanation:

Let east be positive.

$$\begin{aligned}\text{Let :}\quad m_1 &= 2130\text{ kg}\,,\\ v_i &= -18.1\text{ m/s}\,,\\ F &= +8880\text{ N}\,,\quad\text{and}\\ m_2 &= 3260\text{ kg}\,.\end{aligned}$$

$$\vec{F}\,\Delta t = m\,\Delta\vec{v} = m\,\vec{v} - m\,\vec{v_i} = -m\,\vec{v_i}$$

since $v_f = 0$ m/s.

It takes the first car

$$\begin{aligned}\Delta t &= -\frac{m_1\,v_i}{F}\\ &= -\frac{(2130\text{ kg})\,(-18.1\text{ m/s})}{8880\text{ N}}\\ &= 4.34155\text{ s}\end{aligned}$$

to slow to a stop. Thus the force on the second car is

$$\begin{aligned}F &= -\frac{m_2\,v_i}{\Delta t}\\ &= -\frac{(3260\text{ kg})\,(-18.1\text{ m/s})}{4.34155\text{ s}}\\ &= \boxed{13591\text{ N}}\end{aligned}$$

toward the east.

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041 (part 2 of 2) 10.0 points

b) How far would the car move before stopping?

Correct answer: 39.2911 m.

Explanation:

$$\Delta x = v_{avg}\,\Delta t = \frac{v_i + v_f}{2}\,\Delta t = \frac{v_i}{2}\,\Delta t$$

since $v_f = 0$ m/s.

$$\begin{aligned}\Delta x &= \frac{-18.1\text{ m/s}}{2}\,(4.34155\text{ s})\\ &= -39.2911\text{ m}\,,\end{aligned}$$

which is $\boxed{39.2911\text{ m}}$ toward the west.

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042 10.0 points

A 86.4 kg ice skater, moving at 16.1 m/s, crashes into a stationary skater of equal mass. After the collision, the two skaters move as a unit at 8.05 m/s. Suppose the average force a skater can experience without breaking a bone is 4088 N.

If the impact time is 0.11 s, what is the magnitude of the average force each skater experiences?

Correct answer: 6322.91 N.

Explanation:

$$\begin{aligned}\text{Let :}\quad m &= 86.4\text{ kg}\,,\\ v_i &= 16.1\text{ m/s}\,,\\ v_f &= 8.05\text{ m/s}\,,\\ F &= 4088\text{ N}\,,\quad\text{and}\\ \Delta t &= 0.11\text{ s}\,.\end{aligned}$$

From the impulse-momentum equation,

$$F_{av}\,\Delta t = \Delta p = m\,(v_f - v_i)\,.$$

$$\begin{aligned}F_{av} &= \frac{m\,(v_f - v_i)}{\Delta t}\\ &= \frac{(86.4\text{ kg})\,(8.05\text{ m/s} - 16.1\text{ m/s})}{0.11\text{ s}}\\ &= -6322.91\text{ N}\,,\end{aligned}$$

which has a magnitude of $\boxed{6322.91\text{ N}}$. The average force on skater 2 has the same magnitude but opposite direction by Newton's third law. This force is great enough to break a bone.